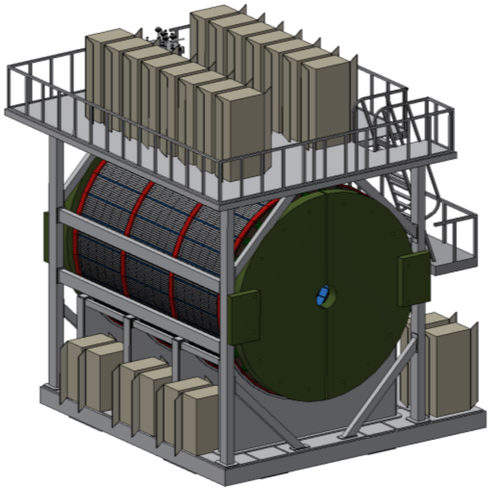
E.Kistenev, BNL



sPHENIX HCal Development

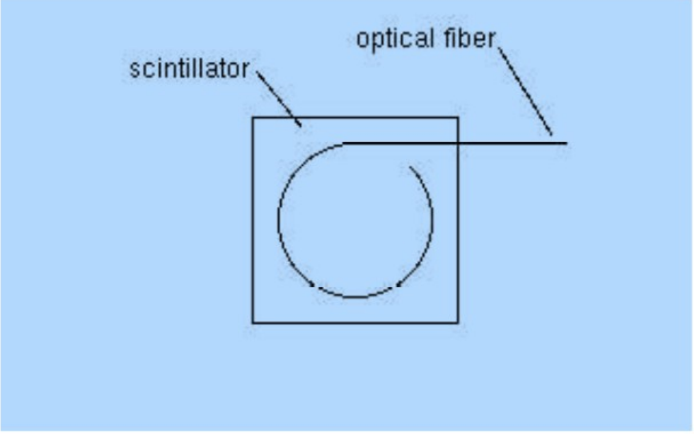
-sPHENIX HCal – how it works

-Fibers and tiles (rules of the game)

-Nonuniformities in the light collection and physics

-Test beam

-Recent developments



We also looked into

- **Optical properties (att.length, extinction etc)**
- **Mechanical properties (fibers and tiles must be robust against crazing, cracking)**
- **Chemical properties (fibers and tiles must be robust against popular aromatic solvents)**

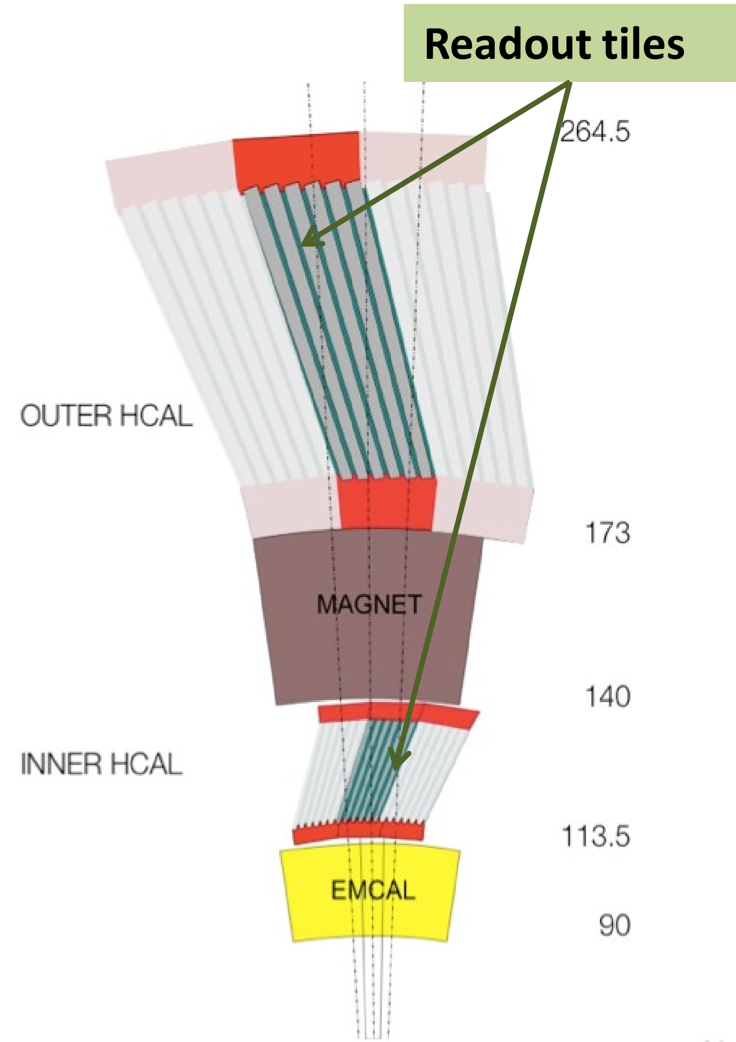
sPHENIX HCal concept

Key points:

- **Tilted absorber plates and scintillator tiles of varying thickness**
- **Tilt is chosen based on simulation to balance azimuthal uniformity and shower smearing between towers (4 tile crossings per MIP in a 5 tiles tower)**
- **Total depth ~6Labs (2Labs (EMC+Inner) + 4Labs Outer)**

Features:

- **Effects of sampling fraction variations with depth are partially compensated by attenuation in fibers and could be fully ameliorated by varying Sc. thickness or reflectivity of coating**
- **Energy resolution "improves" for early showers**
- **Energy leakage is below 5% within our range of <50GeV. Longitudinal segmentation allows for event by event correction for energy leakage (LCG measurements)**
- **Simple to build and calibrate**



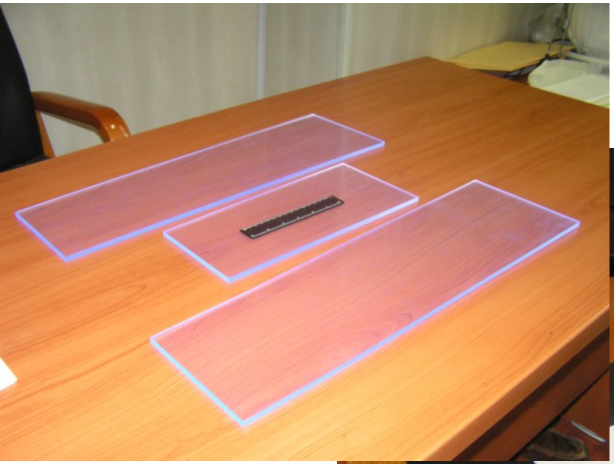
24

HCAL: main parameters

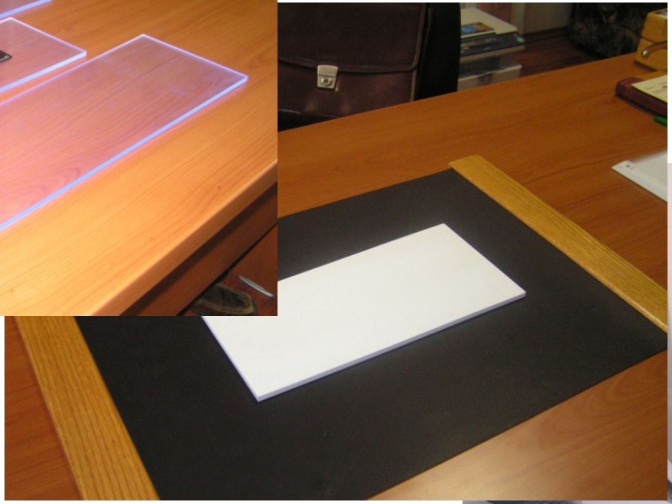
Item	Units	Value	
Total weight	ton	**~ 400**	
Scintillator	ton	~15	
WSF	m	~30000	
Towers		2 (in/out) x 64 (ϕ) x 24 (η) = 3072	
Average sampling fraction	%	HCal Outer	3.0
		HCal Inner	9.0 (5.0)
Sampling cells per tower		5	
WLS Fibers (and SiPMT's) per tower		5	
Light yield (safe bet) (based upon INR/UC measurements, assuming 50% efficient fiber-SiPMT coupling)	pixels per MIP per tile	20	
	pixels per MeV in scintillator	14	
	pixels per GeV in HCAL	HCal Outer	400
		HCal Inner	1200 (670)

sPHENIX test tile Production (Uniplast)

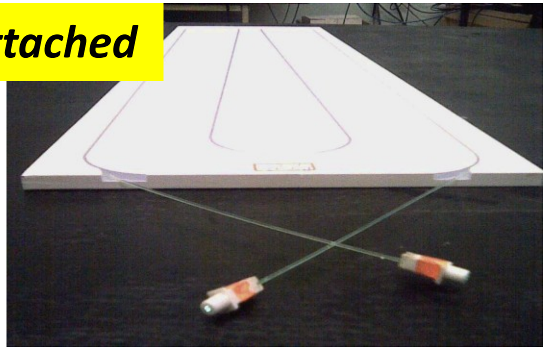
machined



coated

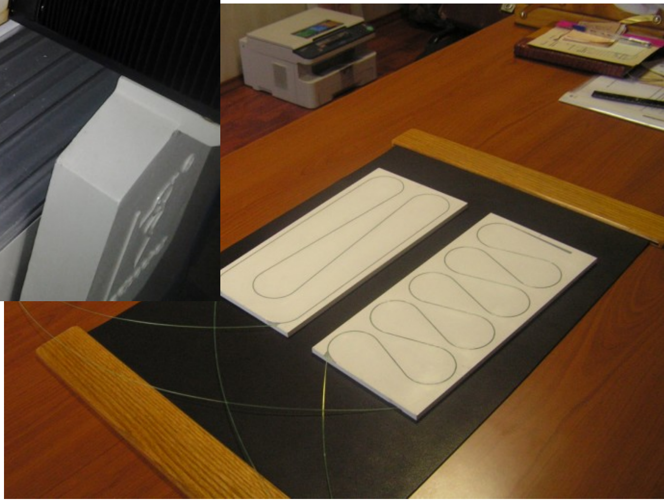


SiPM's attached



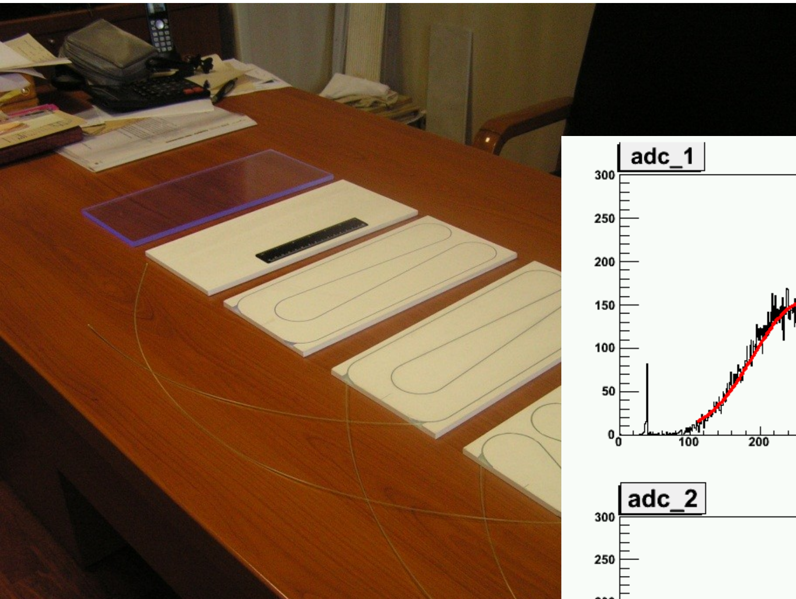
grooved

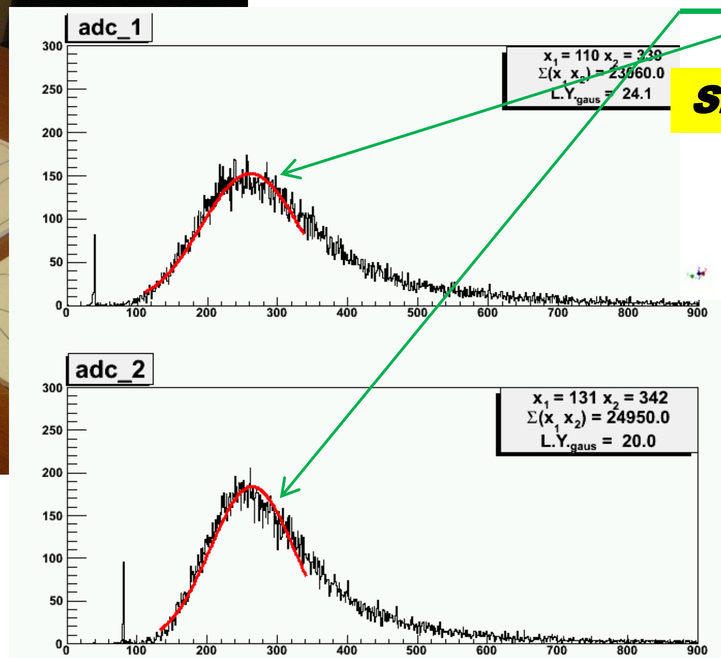
fibers embedded



sPHENIX HCal fiber election:
Kuraray Y11, 1mm, S-type, single clad

SPHENIX test tile light yield (INR, Troitzk)

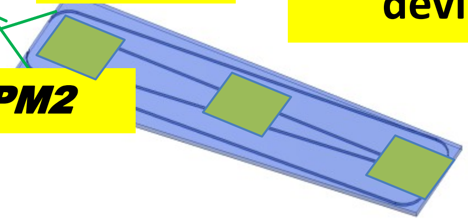




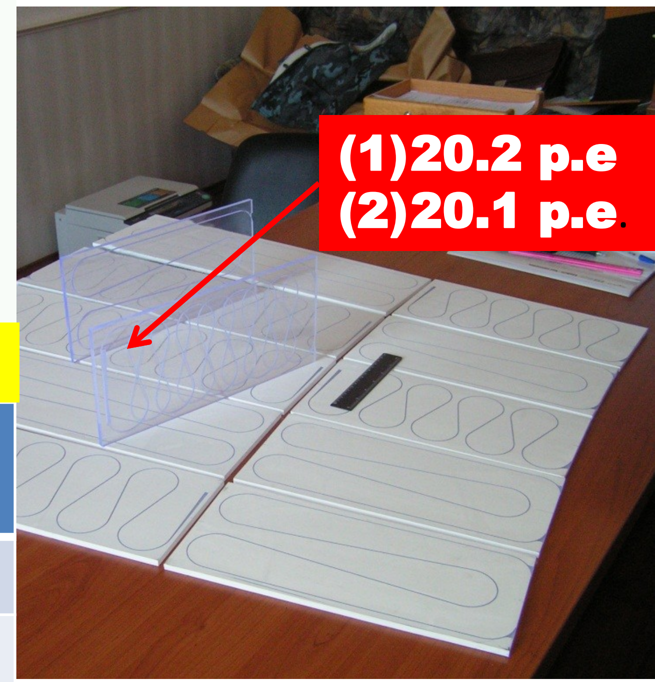
SiPM1

SiPM2

3x3 mm2 devices



Trigger counter 6x6 cm2

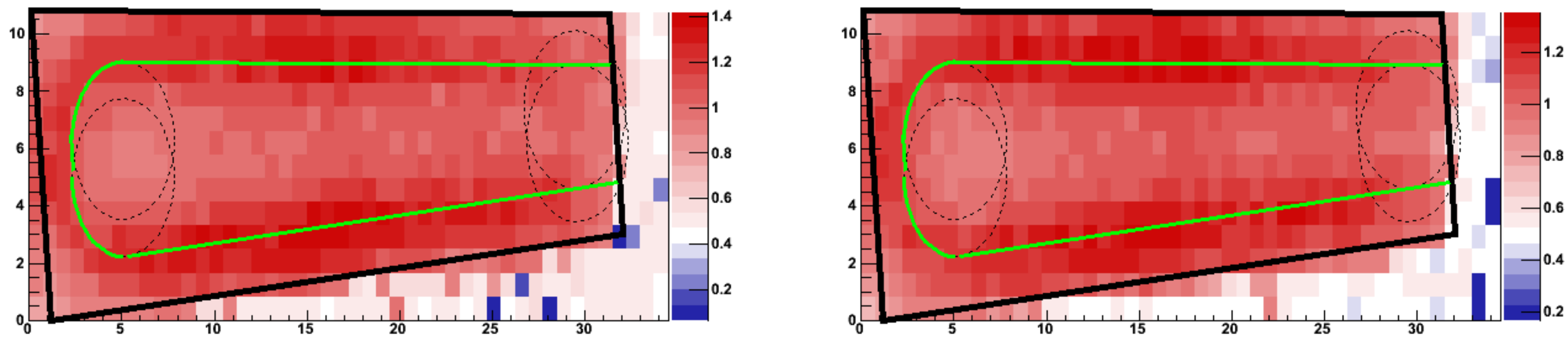


(1)20.2 p.e
(2)20.1 p.e.

First cosmic muon data: 10/01/2012

SiPM	Center	Far end from SiPMs	Near end to SiPMs
1	24.1 p.e	25.1 p.e.	27.6 p.e.
2	20.0 p.e.	20.3 p.e.	24.8 p.e.

sPHENIX test tile nonuniformity of light collection (UC, Boulder)

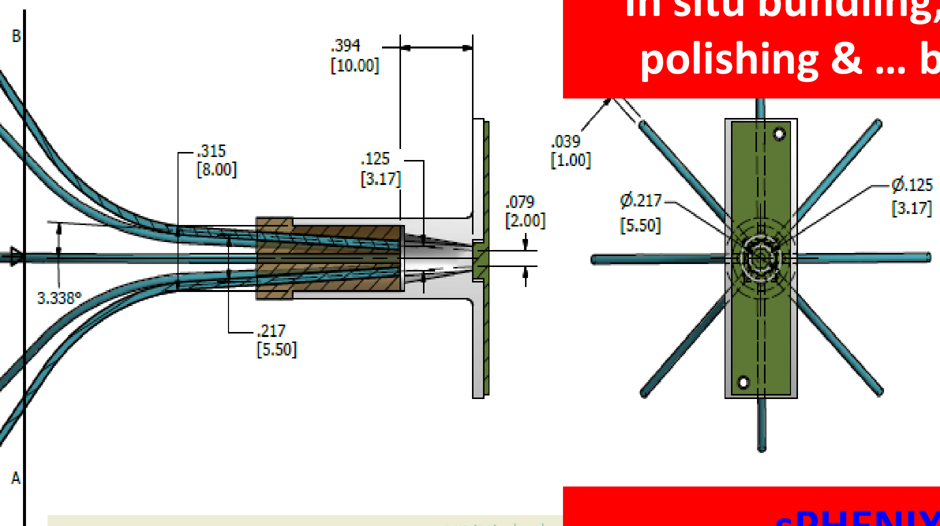


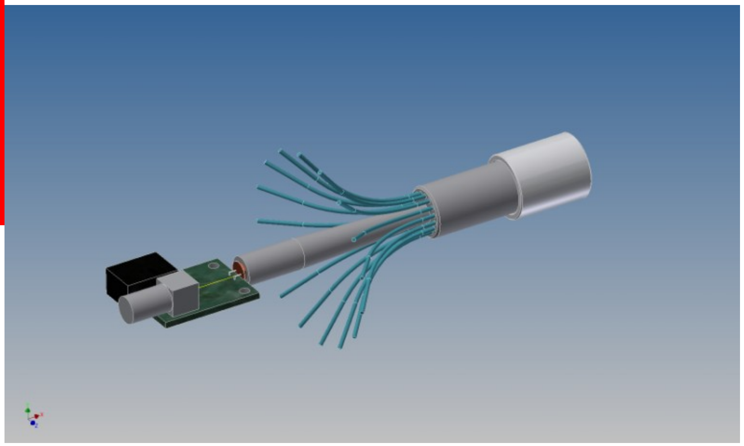
Estimated spread +- 20% of average
Upper limit to RMS of the distribution ~8%
Randomization due to shower spread between tiles ~x2
Upper limit to constant term contribution ~4%

See talk of J.Nagle

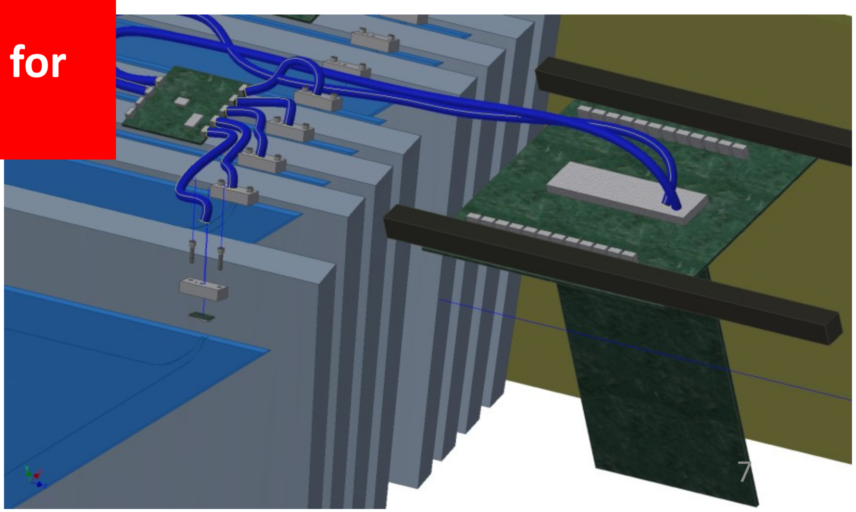
Coupling towers to readout (SiPM's)

TestBeam:
Multifiber coupling.
In situ bundling, cutting, polishing & … breaking





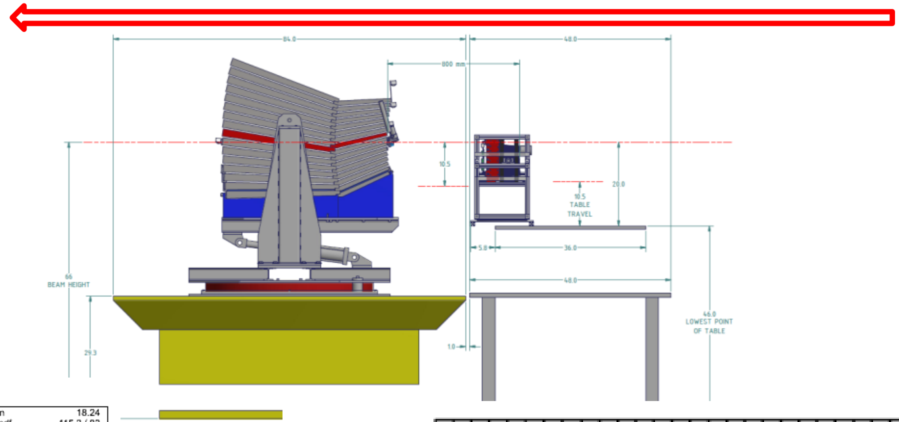
sPHENIX:
One SiPM per tile,
5 SiPM per tower, LED for live/dead control



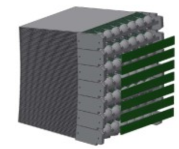
Proto sPHENIX HCal at FNAL (BNL, CSU, GSU, IHEP, LosAlamos, UIUC, T1044)

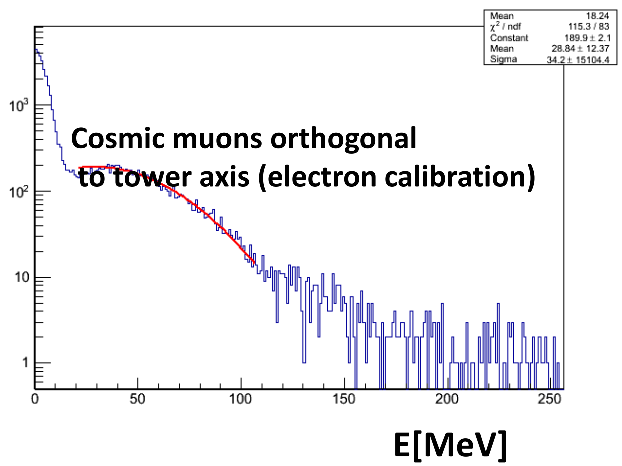
Beam

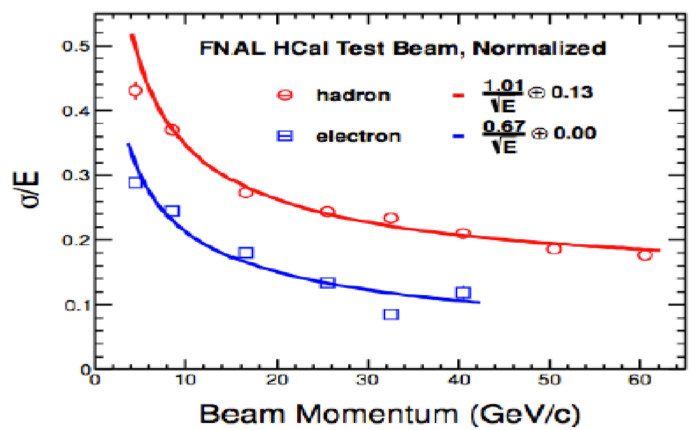
HCal



EMC







- 50 MeV μ-peak is perfectly resolved from the noise what tells us that we have abundant light;
- Improved energy resolution for low energy event component seen in the high resolution section of HCal is beneficial to underlying event – feature of varying sampling fraction

sPHENIX HCal on the world scale

Design: **original**
Mechanical complexity: **minimal**
Performance: **comparable**

Energy resolution:

e.g. inhomogeneities
shower leakage

e.g. electronic noise
sampling fraction variations

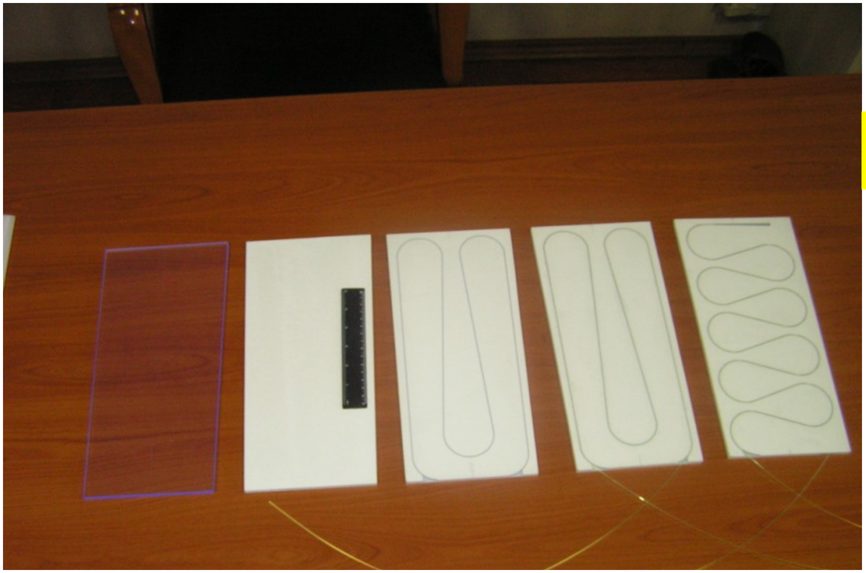
$$\boxed{\frac{\sigma_E}{E} = \frac{A}{\sqrt{E}} \oplus B \oplus \frac{C}{E}}$$

Fluctuations:

- Sampling fluctuations
- Leakage fluctuations
- Fluctuations of electromagnetic fraction
- Nuclear excitations, fission, binding energy fluctuations ...
- Heavily ionizing particles

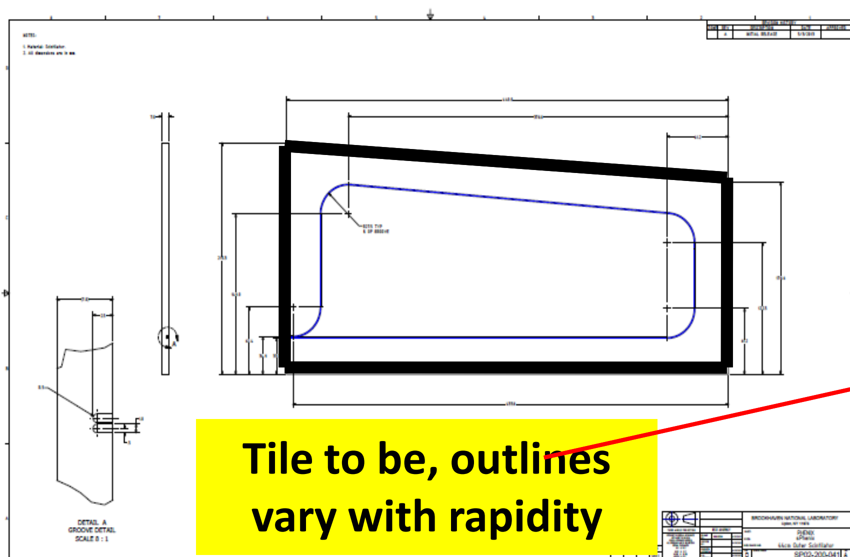
Typical:	**sPHENIX**
A: 0.5 – 1.0 [Record:0.35]	**1.**
B: 0.03 – 0.05	**0.05**
C: few %	**0.05**

sPHENIX Tile Design

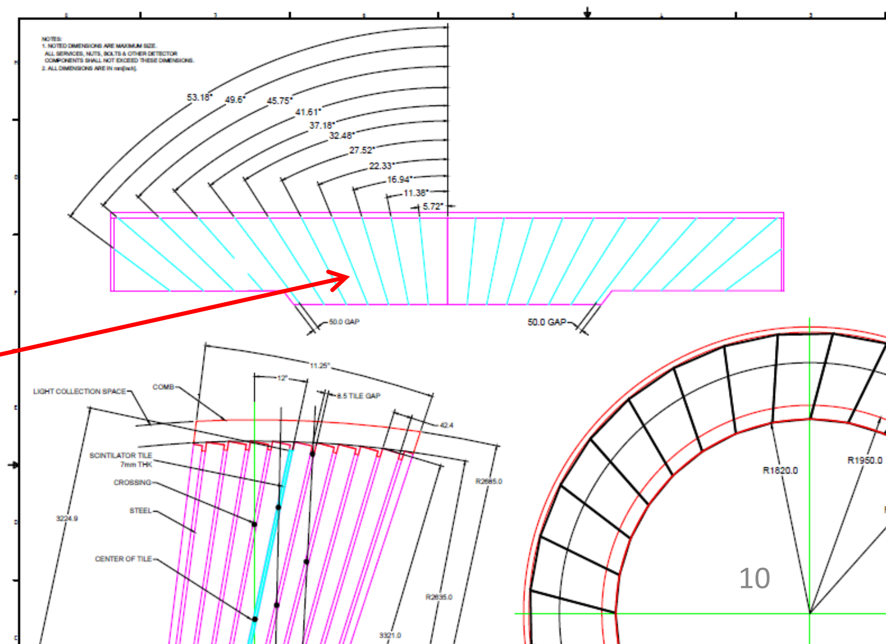


Prototype tiles

-Fiber bending diameter >5cm
-Light path to nearest fiber <2.5cm everywhere



Tile to be, outlines vary with rapidity



Correcting for sampling fraction variations and nonuniformities in light collection (Boulder, Co)

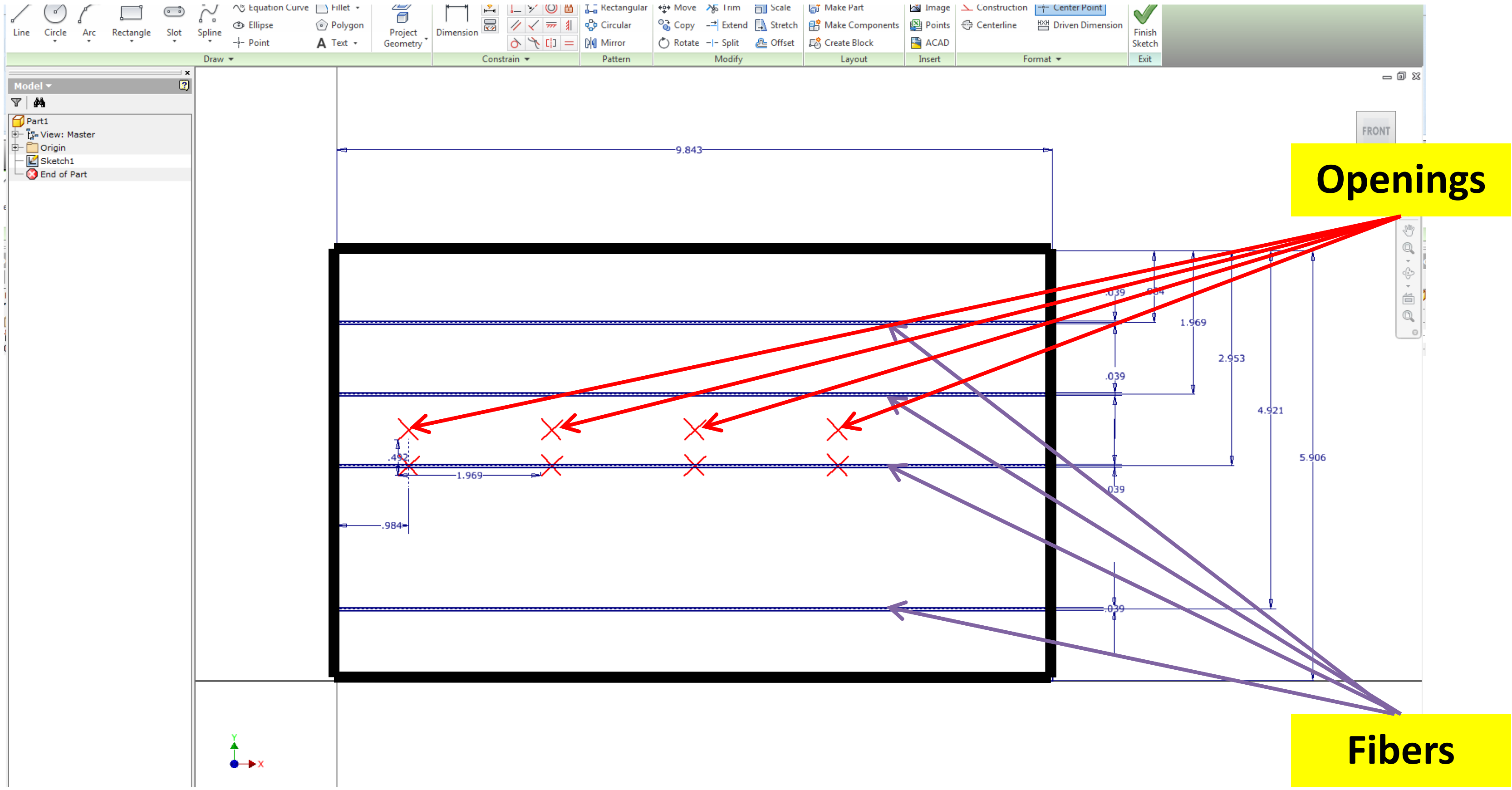
Example Gradient

(not precisely starting at 50% coverage)

Functional dependence: $\frac{15}{npoints} * x^2$

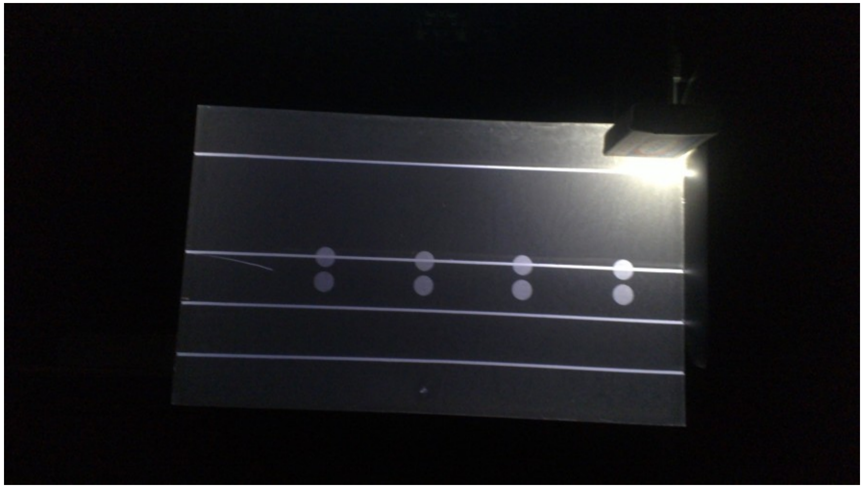
S.Beckman, Boulder, Co

Study is ongoing to implement graded coating



- Square tile with fibers at 2.5cm spacing
- Red crosses are positions of openings in the reflective coating (source exposure through the centers)
- Variations in intensity of light seen by fibers (when compared to undamaged tile) is the measure of light losses through the openings in the coating

Tiles are in Russia (Uniplast) – hope to see them soon. Measurements to follow .....



Summary

- In two years since it was first proposed, sPHENIX tilted plate HCal concept matured from the back of the napkin to the proto calorimeter tested in the beam;
- In the process we perfected mechanical design for the future detector (balancing tilt and shower smearing) and its active media (we have whole production chain set and ready to start delivering the installation ready product);

- We had an excellent year 2014 – we learned that our concept HCal works …. better then expected at low energies;
- We understood what made it possible (varying sampling fraction and attenuation of light in the fibers);
- We also understood the degree to which HCal performance (constant term to energy resolution) can be adversely affected by varying sampling fraction;
- We are currently developing the technology for laser modifications to the reflective coating (graded coating) leading to controllable light loss from the tile. We are not starving for photons, loss of light will not affect the gain in stochastic fluctuations due to sampling fraction increases towards inner radius of calorimeter. If successful and cost effective we will use it to further improve calorimeter performance.
- Alternative (backup) option for improving uniformity of HCal will be to mechanically shave the tiles before coating;

Looking forward towards next spring at FNAL